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Army Engineer Waterways Experiment Station
Vicksburg, Mississippi

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FOREWORD

The Military Evaluation of Geographic Areas project (MEGA), U. S. Army Materiel Command Project No. 1-T-25001-A-131, has as one of its objectives the description of terrain factors in terms of their effects on military activities. Presentation of terrain-effect data in the form of tactical maps is considered to be one of the essential products of the project. To be most useful, such a map must contain considerable detail; but it must also be of a useable size, which implies generalization, and this in turn implies loss of detail. A possible solution for this dilemma is offered in this paper.

The paper was prepared for presentation at the 1964 Regional Convention of the American Congress on Surveying and Mapping, Kansas City, Missouri, 24-26 September 1964.

RETENTION OF DETAIL IN MAP GENERALIZATION

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Abstract

The distribution of things in any approximately homogeneous population can be adequately described by a sample which is coincident with a minimal area, and the total area occupied by the population can be considered as composed of multiples of this minimal area; this minimal area is here called the "structural cell." The smallest area which can be depicted on any map is a function of the map scale, being the smallest area in which a legible map symbol can be drawn; this area is here called a "mapping cell." If a map is initially compiled at such a scale that the smallest structural cell characterizing the populations being mapped either coincides with or is larger, *at the map scale,* than the mapping cell, all distributions can be mapped with nearly complete fidelity. The reliability of such a map approaches 100 percent. Scale reduction of such a map implies that one or more of the structural cells become smaller than the mapping cell at the reduced scale. Normally, this means that areas of lesser extent than the mapping cell cannot be shown and are therefore merged into the map unit of greater occupance, resulting in a map unit characterized in the legend as a single population, but in fact representing areas composed of two or more populations. Such a map unit has a "reliability" of substantially less than 100 percent. Retention of detail with scale reduction depends upon recognition of the scalar relationships between the mapping cell and the structural cells of the populations being mapped. The boundaries between the units are generalized according to a set of prescribed rules, and a legend is designed consisting of diagrammatic representations of "unit areas" in which the relative proportions, as well as the schematic positional relations of all populations comprising the generalized map unit are identified.

Presented at the 1964 Regional Convention of the American Congress on Surveying and Mapping, Kansas City, Missouri, September 24-26.

Retention of Detail in Map Generalization

It is commonly held that compilation of a small-scale map from a large-scale map, or from raw data, necessarily involves simplification or the elimination of unessential detail. Miller and Voskuil (1964) express the attitude that "generalization is a process of evaluation, selection, and emphasis," and after developing this concept, conclude that every thematic map presents a special problem, and "although the objective of the map must be kept constantly in mind, freedom of expression must be permitted."

A map is, almost by necessity, usually smaller than the territory represented, and the reduction of scale is accompanied by a proportionate loss of detail, which is in other words a loss of information. But might we not agree that it would be useful not only to minimize this loss, but also to be consistent in the selection and elimination of that which is lost? It is not difficult to conceive of a situation wherein "practical experience combined with common sense and a flair for the subject" (Miller and Voskuil 1964), may be not only inadequate but even dangerous.

Fig. 1 shows a portion of a "trafficability map" of Fort Stewart, Georgia, (USAEWES 1954). The caption states that "This map shows intelligence on cross-country (off-road) movement *generalized to correspond with the scale of the map.** Evaluations different from those indicated hereon may occur *in areas too small to delineate.** Hence this map does not preclude necessity for reconnaissance and other detailed intelligence for tactical operations."

The question is, then, does it accomplish its objective? In a crude sort of way, probably it does; but in a specific way, most assuredly it does not. Would it not be helpful to know *how much* reconnaissance effort would be necessary in various places, or, precluding the opportunity for reconnaissance, to know the *probability for or against* a successful traverse between two given points? What rules or guidelines did the authors use to accomplish their generalization? How consistently were they applied? In short, how *reliable* is this map?

* Present author's italics.

Again: a comparison of the legend with the map suggests that while a more or less distinct directional pattern exists, nonetheless much of the area is trafficable at least during the dry period, being classified in the A, B, and C categories. But a closer study of the accompanying text reveals that the C areas[†] "will be passable during dry periods, but *doubtful and impassable local spots (too small to map)** will occur [into the dry season, i.e., into early June]." For an operation in June, then, the legend is misleadingly favorable, whereas the descriptive material promotes hesitation. What was considered "too small to map"? How frequent or numerous are these "local spots"? How distributed? What, indeed, is the probability of a successful operation in June?

First, that we might not be deluded, we must admit, and keep firmly in mind, two undeniable and imperative facts: (1) With no exceptions, a map can show locations and distributions of only *classes* of things--whether events, objects, or whatever; a corollary of this is that where the data being classed represent a continuum there will inevitably be borderline cases, requiring subjective decisions as to which "class" or mapping unit these borderline data should be assigned; and (2) no map can ever be better than the data upon which it is based.

These two facts are irremediable limitations of every map. The implications are that subjectivity can never be completely eliminated from the mapping process, and that its effects will be functions of the rigidity with which the class limits are defined, and the quantity and quality of the data. It is apparent that the reliability of any map will be a function of the effort expended, first in the data collection, and second in the care with which those data are displayed.

Let us now apply these general concepts concerning the nature and limitations of maps to the construction of an improved version of the trafficability map, and, by extension, to the proper construction of any map on which gross generalization would seriously detract from its value. It is assumed that the purpose of the map would justify the effort of gathering detailed information, *but* that this information must be displayed on a map of convenient size.

[†]Specifically C_1, the better of the C group, but C_2 is similarly described.

*Present author's italics.

A standard method of measuring trafficability—the ability of a soil to support traffic by a given vehicle or class of vehicles—is to obtain two numbers, the cone index and the remolding index, and combining these to produce a single number, the rating cone index (USAEWES 1956). It is not necessary to detail here the sampling procedure, but these indices are [illegible]sions of certain mechanical properties of the soil, and are measured by a point sample system—i.e., a sample which requires very little space. It is therefore entirely possible to sample virtually every square inch of soil, and to map the data at a scale of 1:1. Such a map would have a reliability of 100 percent. But while possible, it would hardly be practical—for obvious reasons, not the least of which is that the vehicle occupies an area of more than 1 square inch.

Let us assume that the given vehicle occupies 100 square feet, or thereabouts. It would not be impractical to sample at this density, nor would it be impractical to map points at this density, at a very large scale, say 1:1000.

Let us therefore decide that the density of samples in the field will be such as to reveal areas of this size, and the first map shall be at such scale that this area will be represented by a square 0.01 foot on a side—a convenient minimum size for plotting numbers on a map.

Now, recall that the rating cone index is a ratio—i.e., a dimensionless number. Realizing this, it is apparent that it would not be realistic nor meaningful to map each number, because in fact all those below a certain number represent "no-go" situations, or impassable conditions, and all those above that number permit "go"; but "go" situations can be further subdivided according to *degree of go,* i.e., difficulty of passage, as for example, first gear, second gear, third gear—or on the basis of season, etc.; in the present case both of these, and perhaps others. The upper and lower limits of these "degrees of go" are determined by actual field trials, and thus will be determined the "classes" of things to be mapped—i.e., the "mapping units." (Whether the numbers are plotted on the map and the group boundaries then determined, or whether the data are classified before being mapped is really irrelevant.)

Now, as a matter of review, we have determined the classes of things to be mapped, and we have determined that some of these classes offer critical conditions, even though their occupance consists of quite small, discontinuous patches. We have therefore decided to obtain a rather dense sampling, and to map these at a rather large scale. A segment of the resultant map might look like that shown as fig. 2.

But we have also stipulated that the final map must be "of convenient size," and obviously a map at this scale must be much too large to conveniently serve its purpose (planning of tactical operations), and therefore it must be reduced, say to a scale of 1:25,000, the scale of fig. 1; and since at least some areas of the critical classes are quite small, it is evident that at such a reduced scale they would be very small indeed--as witnessed by the photographic reduction of this map, shown at lower right in fig. 2. Many if not most of these small areas would in fact disappear, being "too small to map." They would not, unfortunately, lose their significance in the territory.

Determine the occupancy of the various "types," or mapping units, in the area being mapped.

C_1 = 1.3%**	B_2 = 6%	C_2 = 67%
D_1 = 21.5%		C_3 = 3.2%

But notice that all of these "types" except C_3 can be retained at the reduced scale; we therefore need not be concerned with them. We are concerned only with the loss of C_3, and with its relationship with C_2. We therefore need not be concerned with its occupancy relative to the *total* territory, but only with its occupance relative to C_2. If we let $C_2 + C_3 = 100\%$, and then measure the area of C_3 relative to this, we find that $C_3 = 5\%$. We notice also that the patches of C_3 are more or less random within the greater area of C_2. We are now prepared to undertake the reduction. It is shown as fig. 3.

Now at first glance this looks not unlike a tiny portion of the map of fig. 1, but it differs in one important respect. Note that in the legend, the mapping unit indicated as C_2 is symbolized as a composite comprised of the two types C_2 and C_3, and that not only is the occupancy of C_3 stated quantitatively in terms of percent of C_2, but its distribution can also be interpreted.

** This example is not exactly correct, since fig. 2 represents only a very small portion of the total area being mapped. A false impression can be avoided here by forgetting fig. 2 for a time, and accepting these calculations as having been based upon the total area of Fort Stewart.

This has been accomplished simply by adding to the legend a descriptive symbol consisting of a square divided into 100 units (i.e., a grid 10 × 10 units) so that each unit represents 1%, and then distributing 5 units (thus 5%) randomly within it. Somewhere in the descriptive text the type C_3 would be described just as are the other types.

There are some variations on this theme which should be examined:

First, suppose that type C_3 were not so uniformly distributed throughout type C_2, but instead only in some places were these "persistent mudholes" aggregated. In this event, we should have delineated on the map the areas wherein these aggregations occurred, indicated the areas so delineated as C_3 on the map, and supplied an additional symbol in the legend, as shown in fig. 4.

Next, suppose that these "persistent mudholes" which we have designated C_3, while exhibiting the same pattern and distribution as suggested above, actually in places occupied more of the territory than C_2, i.e., assume that there is in places a dense pattern of these mudholes set into a continuous reticulum of C_2, such that in these places the mudholes occupy 65% of the area, and C_2 occupies 35%. There is no doubt that by the standards used in preparation of the map of fig. 1, these places would, on the basis of occupancy, have been delineated as C_3, and mapped as such, with the result that the C_2 would have been lost in these places. The interpreter would then have presumed that the areas are impassable until later in the spring than the C_2 areas, whereas in fact with a carefully chosen (albeit perhaps tortuous) route, they would be passable.

Our solution to this problem would consist of, as before, mapping these places as C_3, but then describing them in the legend as shown in fig. 5.

Also, as a corollary of these two points, it should be noted that in the territory the densities of mudholes might be variously distributed. For example, both of these conditions might exist, as well as places with intervening densities. In this event, a mapping unit would be erected for each recognizable and delimitable population density. Our success in this would depend upon our ability to establish significant population density classes, and to recognize these on the ground.

Finally, it must be observed that in our example we assumed that these "persistent mudholes" exist only within type C_2, whereas in fact, according to the descriptive text, they are present also in C_1 and in B_1 and B_2.* Obviously the example is somewhat oversimplified, but whatever the conditions, an approach to a solution should be becoming evident.

It is now necessary to introduce some important concepts, which we have in the preceding discussion invoked without acknowledgment. These are the concepts of "homogeneity," of the "structural cell," and of the "mapping cell."

The concept of homogeneity is not new; it has been the subject of much discussion by both geographers and plant ecologists (Goodall 1952, Greig-Smith 1957, Cain & Castro 1959, Duncan *et al* 1961), and though this discussion has been both pro and con, it has not really acquired the aspects of a controversy. The main theme of the discussion revolves about the question of whether or not it is a useful concept, in that it is often difficult to draw the limits to that which is to be considered a homogeneous population. Without reviewing the literature, then, it will be useful to set forth here an interpretation of the concept.

As the word implies, homogeneity refers to the state or quality of uniformity, but this simple definition is not quite adequate in the present context. It must be qualified by a definition of the members of the population; for, in the words of Goodall (1952, p 224), "Romell (1925, 1926) brought forward the valuable idea that homogeneity must depend on scale--that while vegetation (or any pattern) may appear heterogeneous when considered in detail, on a larger scale it may be homogeneous." Homogeneity is, after all, a relative matter.

If, for example, we are concerned with a stand of trees, we can define the population as being uniform *on the basis of stems per unit area*, provided any randomly selected sample of unit area has approximately the same number of stems, regardless of the size of the stems, regardless of the species, and regardless of the proportion and distribution of the species relative to each other. But if *species* is the subject for consideration,

* It should be noted that these "persistent mudholes" in unit C are not enclaves of unit B; nor are those in unit B the same as those in unit C. The differences are seasonal variations in drying time, due partly to soil and partly to elevational differences.

and if half of the stand consists of oaks and the other half consists of pine, then the stand must be regarded as consisting of two populations. But again, if the two species are uniformly distributed in a mixed stand, then this will be a homogeneous mixture.

If a wooded area is occupied by trees uniformly distributed except for scattered grassy openings, then either the trees constitute a homogeneous assemblage and the openings constitute enclaved but discrete homogeneous assemblages, or the two together *en toto* constitute a homogeneous assemblage consisting of a mixture of trees and grassy openings.

Thus a population may be spoken of as being homogeneous, by which is implied that the population is uniform with respect to the distribution, occurrence, size, or other specified attribute of its members, whether these "members" be stems, oak trees, oak trees with a knot on the third limb, corn patches, barren hillsides, or whatever.

To go one step further, it is often helpful to recognize that there are different *levels* of homogeneity, and there are different *degrees* of homogeneity. The difference between these is subtle: basically, degree of homogeneity refers to the amount of variation permitted in the population, i.e., the degree of refinement or crudeness of the classes; whereas level of homogeneity refers to the definition of the members of the population, i.e., to the kind of thing being classified.

Now, often there is a degree of subjectivity involved in defining the level and degree of homogeneity which is to be accepted as a mapping uni but this subjectivity can be minimized. The degree of homogeneity is a function of purpose, and the level of homogeneity is a function of scale. In the development above of the trafficability map, the degree of homogeneity was minimized experimentally when the classes of rating cone index were established by field trials, and the level of homogeneity was rather rigidly established when it was decided to make a very dense sampling and to map these at a very large scale. When this map was reduced, the effect of reduced scale on this level of homogeneity, i.e., the loss of detail, was minimized by the device employed in the legend.

The plant ecologists' interest in the problem of homogeneity derives from a desire to minimize the sampling procedure, but to do so without destroying the validity of the sample. Whatever the difficulties attendant upon delimitation of a homogeneous population, such a population, once delimited, must necessarily be subject to statistical analysis.

Statisticians are quite convinced that, given a population, there is a minimum sample by which that population can be described with any desired reliability, and furthermore, the size of that minimum sample can be predicted on the basis of a relatively small preliminary sample. It would seem that with things distributed areally, and when it is the spatial relationship which is of interest, this minimum sample would become a minimum area, and it is no doubt an application of this idea from which has developed the concept of a "minimal area" (Goodall 1952, Greig-Smith 1957, Cain & Castro 1959).

"Minimal area," as defined by Cain & Castro (1959, p 167), is "the smallest area that provides sufficient space or combination of habitat conditions for a particular stand of a community type to develop its essential combination of species or its characteristic composition and structure."

Although this idea has been the subject of much discussion and consternation (see references), there can be little doubt that, conceptually, it is a valid statistical measure--the discussion revolves about an uncertainty as to its application, not its validity--and it is not necessary here to review this discussion, nor to dwell upon the minimal area concept. It is sufficient to state that by an application of this concept to the special interpretation of homogeneity presented above, there has evolved the idea of a "structural cell."

In its simplest form, this concept postulates that there exists a minimal area for each and every attribute or characteristic of any given plant assemblage, and that any or all of the minimal areas may be different from any or all of the other minimal areas for the attributes of the given assemblage. In other words, a total plant assemblage consists not simply of a collection of species, but of a collection of different populations, the "members" of which are defined as the different characteristics of the plants.

Let "structural cell" be defined as "the minimum area which includes a statistically significant sample of all of the important variations, in terms of selected parameters, present in a given plant assemblage." It is thus not quite synonymous with the "minimal area" as conceived by the plant ecologists, since it depends upon a definite statement of the attribute or attributes by which it is determined; and as such may be a composite sample of several "populations" (granted, "species" may be one of these, but only one) depending upon the purpose of the sample. The problem, then, is to determine that sample size which minimizes the variance of the component means.

Because areal distributions of various things, e.g., tree stems or "persistent mudholes," are of prime consideration in cross-country mobility, the Waterways Experiment Station (USAEWES) has explored the structural cell concept with some intensity, and with some rather interesting results (Mills 1963, Marshall Univ. 1963, 1964). Again, there is not space here to elaborate these results; it is sufficient to state that not only does the structural cell provide a valid measure of the dispersion of a population, but it can also be used to determine the limits of that pouplation. And although it should be obvious, it might not be amiss to point out that the size of the structural cell is a function of the density of the population.

It remains now to exploit these two concepts in the mapping process. It has already been shown that the smallest area that can be shown on any map is dictated entirely by mechanical considerations--it must be large enough to accommodate a legible symbol. This, then, shall be the definition of a "mapping cell"--the smallest area which it is possible to draw and identify on the map being constructed, i.e., in which a legible symbol can be placed.

Though the actual size selected as the mapping cell is somewhat optional, it is controlled to some extent by the complexity of the symbols to be portrayed, or by other considerations. But once selected, it represents the absolute minimum mappable area of the territory, and the area of the territory which it represents is a function of the map scale. In the example above, a 0.01-foot square was adopted as the mapping cell, and this represented 100 square feet on the ground. This unit was chosen in this case for the reason that it is desirable to keep both sides of the scale in the same units, in this case feet. It could as well have been a circle of diameter 0.1 inch, or a few millimeters, etc.

Since the mapping cell is the smallest definable area on any given map, it follows that the mapping scheme employed must include provisions for characterizing an area of that size as an homogeneous unit. But recall that a structural cell is the smallest area by which an homogeneous population can be adequately defined and described. These two assertions are almost parallel--the mapping cell is to the map what the structural cell is to the territory. Therefore, if a map is initially compiled at such scale that the smallest structural cell characterizing the populations being mapped either coincides with or is larger than the mapping cell, the distributions of all the populations can be mapped with nearly complete fidelity. The reliability of such a map approaches 100%.

Again in the example above, the structural cell concept was invoked, but only in a subtle way. In the first case, the *size, per se,* of the mudholes determined whether or not they would be mapped,and it was thus the *mapping cell* which exerted the most direct control on the mapping units. In the subsequent variations on the example, however, i.e., those in which were recognized various "densities" of the mudholes, the *population densities* of the mudholes, and *not* their size, formed the basis for delimiting the mapping units. The mudholes, *per se,* became the "members" of the populations, and the structural cell concept was invoked in delimiting these populations on the basis of densities.

Because scale reduction inevitably involves generalization of detail, the highly complex boundaries between mapping units drawn at large scales become progressively less complex as scales are reduced. The process of scale reduction then resolves into the development of an objective and consistent method of generalizing boundaries.

By definition, the small-scale map has a mapping cell which covers a larger area *on the ground* than does the mapping cell of the large-scale map.

Thus if the mapping cell of the proposed small-scale map is increased to the scale of the large-scale map, it will be larger than the mapping cell of the large-scale map. This is illustrated in fig. 6; if the mapping cell is a circle with diameter 0.1 inch, the ground diameter at 1:20,000 is 56 yards, and at 1:250,000 it is 694 yards.

Now, if the center of the enlarged small-scale mapping cell is passed along a unit boundary on the large-scale map, and if on either side of the boundary, lines are drawn tangent to the mapping cell as it is passed along, then a band will be generated along the original boundary. In fig. 7, the boundary between prairie and forest is drawn on map A at a large scale. Assume that it is to be redrawn at a smaller scale, such that it requires a mapping cell with diameter equivalent to the 100-meter bar at bottom of the diagram. Clearly, a broad band will be generated to include the entire area of interfingering, plus a little more on each side (fig. 7B). The small-scale boundary equivalent is then determined in either of two ways: by bisecting the generated band (bisection method) (fig. 7C); or by establishing a third mapping unit bounded by the tangent lines (tangent method) (fig. 7D).

With either method, the result will be a drastic generalization of small crenulations, the elimination of tongues and enclaves which cover less than half the area of the mapping cell, etc. The characteristics of the resultant maps, however, will be quite different.

With the bisection method* (fig. 7C), the distribution pattern of the original units is lost, so that the reader cannot identify places where enclaves or tongues have been generalized out. All that is retained is a positive statement of the reliability.

With the tangent method (fig. 7D) not only is there a positive statement of the reliability, but also the pattern of distribution is retained, enabling the reader to identify the places where tongues, etc., have been generalized away. The resultant map, however, is necessarily somewhat more complex than is the one resulting from the bisection method.

* Bisection of the generated band is accomplished by inscribing within it another series of circles, this one a single row with variable diameters, tangent to the boundaries of the generated band. A line connecting the centers of these circles then bisects the band. Some of these circles have been retained on fig. 8.

This leads to the seemingly anomalous statement that, in order to retain a large-scale distribution pattern at reduced scales, it is often necessary to employ a larger number of mapping units. And indeed so--generalizations imposed by scale may require a more complex symbolic structure to avoid loss of meaning.

Inevitably, generalization by either method will result in some bands too narrow, and areas too small, to map at the reduced scale. The advantage of the technique lies in the fact that it offers a way to treat these situations consistently and quantitatively, and to retain the boundary relationships which otherwise would be lost. Some examples of how these areas "too small to map" will occur are shown as "denied areas" on fig. 8, which also shows the results of applying alternative methods of generalization.

Which method of generalization is employed for any given case is optional, being in part dependent upon the willingness to compromise reliability for simplicity. This in turn is somewhat dependent upon the frequency and nature of the denied areas. If they are infrequent, then they will have small influence on the reliability; if they are frequent, but there are not recognizable repetitive patterns, the loss of reliability might be more acceptable than the creation of too many complex mapping units. In any case, the decision as to which method will be adopted will be somewhat dependent upon the purpose of the map.

Unfortunately, purpose is not always easy to define. If, for example, the purpose is to convey as much information about the vegetation in a desert area as is possible to retain at some given small scale, then there might occur a case in which it will be necessary to decide which should be portrayed with greater fidelity--a cactus assemblage with moderately wide-spaced but loose-jointed, hazardously spiny characteristics, or an horrendous cat's-claw thicket with its less severe (albeit respectable) spines but impenetrable entanglement of branches. The problem in this case is to decide which has more "information content"--a decision which might be equally difficult whether the purpose were for the planning of cross-country movement of military troops and equipment or for the analysis of biological relationships.

In order to assure consistency in dealing with these situations, it might be useful to develop a set of rules, based upon whatever considerations seem most appropriate to the circumstances, and this set of rules would be included in the descriptive text accompanying the map.

Figs. 9A-D illustrate possible solutions to other situations. Obviously, in each of these cases there has been employed a device for determining the confidence values for each mapping unit at the small scale. This is, of course, as was done in the example of the trafficability map, nothing more than measuring the occupance of all the classes of things within the re-created units on the large-scale maps, and transferring these to the legend symbol prior to the actual reduction. The greater the reduction, of course, the more complicated must be the legend.

It must not be forgotten that the occupance values for a given mapping unit are computed upon the basis of the occupance of that unit *in the total area being mapped.* The implication is that for units which occur in small disconnected areas scattered variously over the territory, there must be two characteristics common to every area designated as that unit; to wit: the component classes of things included in that unit must occupy approximately the same relative proportions of each area designated as that unit, and they must also exhibit a similar distribution pattern in each area designated as that unit.

What is to be accepted as "approximately the same proportions" and "similar" distribution pattern will, of course, be related to the acceptable limits of variation in the classes of things being mapped, and, again, to the willingness to compromise reliability for simplicity. Both of these problems have been discussed above. The important point here is that the legend diagram is the definition of the mapping unit, and therefore anything mapped as that unit must be properly represented by the diagram, and interpretable from it.

Finally, since the final map is entirely dependent upon the size of the mapping cell used in its construction, the cell must always be defined on the map. It is at least as important as the scale and the north arrow.

Though this scheme seems a bit complicated, it is in fact only slightly more time-consuming than conventional methods, and since it is almost entirely mechanical, it is consistent; if the final map is the result of a group effort, its reliability is not a variable dependent upon the arbitrary decisions of the different draftsmen. Not only this, but it also tells the reader how accurate it is.

Fig. 10 is a portion of a very detailed map of the vegetation on the Yuma Test Station in Arizona. The preliminary maps were prepared by very careful analyses of aerial photographs, and varied in scale from about 1:6000 to 1:16,000. These were then reduced to 1:163,000, according to the procedure set forth here. On this map, unit A (the symbol at the top) is mapped as class 1. The confidence value, however, is only 82. The remaining 18% of the area consists of 12% of class 12, and 6% of class 8. Further, both classes 8 and 12 occur as tongues extending into class 1 areas, and furthermore, the tongues of class 12 areas are usually terminated by patches of class 8 areas. Thus if the reader has a precise description of the classes, he can draw a rather accurate picture of the characteristics and the distributions, even from this small-scale map.

Thinking in different terms, it is often useful to interpret things in terms of probabilities. In effect, the legend diagrams and the confidence values are statements of probabilities. Because the confidence value is a statement of the proportion of the area occupied by a given class within a map unit *as a whole*, it follows that a number of points selected at random within that map unit would, on the average, fall within the given class the percentage of times represented by the confidence values. For example, a parachutist bailing out over an area mapped as unit A in fig. 10 would stand approximately one chance in 17 of landing in type 8. Another interpretation would be that, if types 12 and 8 are hazardous drop areas, a drop in unit A could be expected to be approximately 82% effective.

A map which permits interpretations such as these would seem a thing devoutly to be wished.

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List of Illustrations

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FIG. 2. PRELIMINARY MAP
SCALE - 1:1000

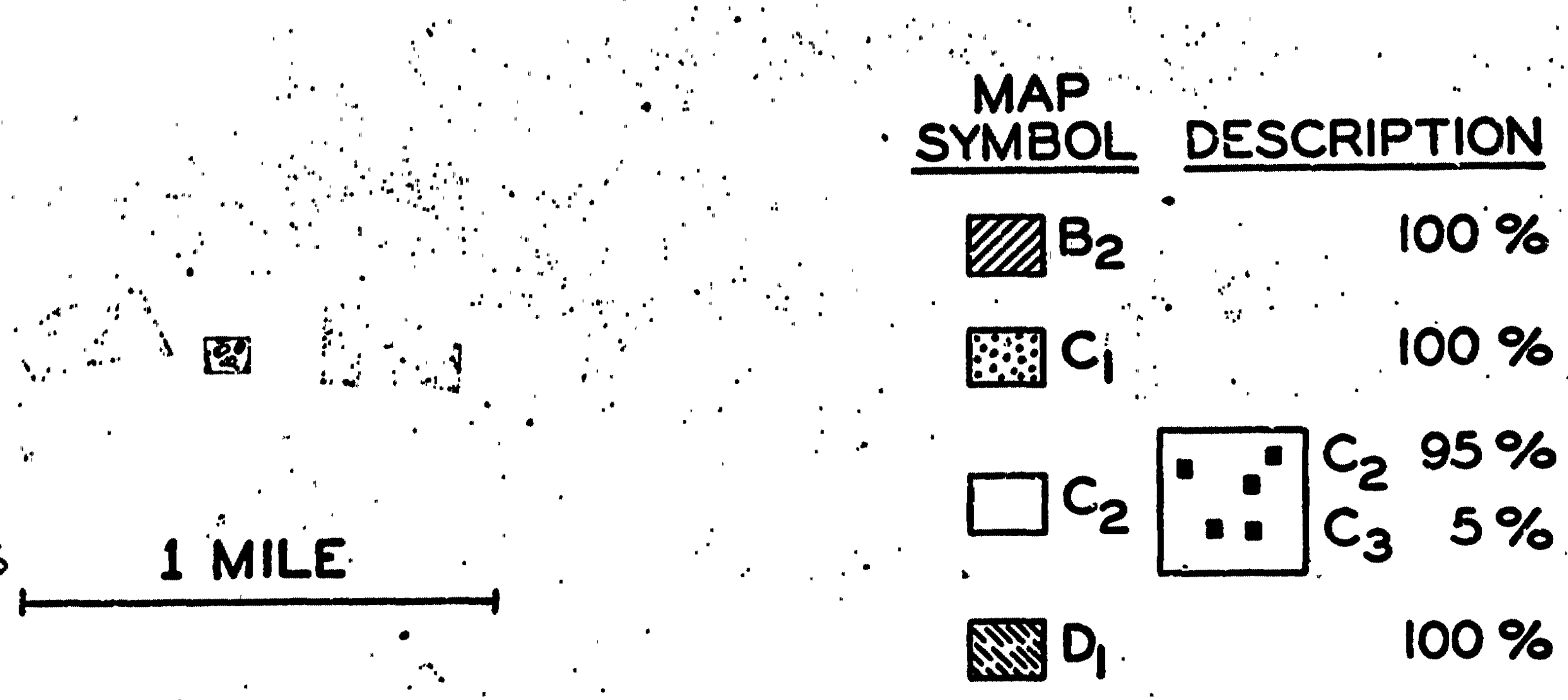


FIG. 3. TRAFFICABILITY MAP AT SMALL SCALE PREPARED FROM PRELIMINARY MAP OF FIG. 2

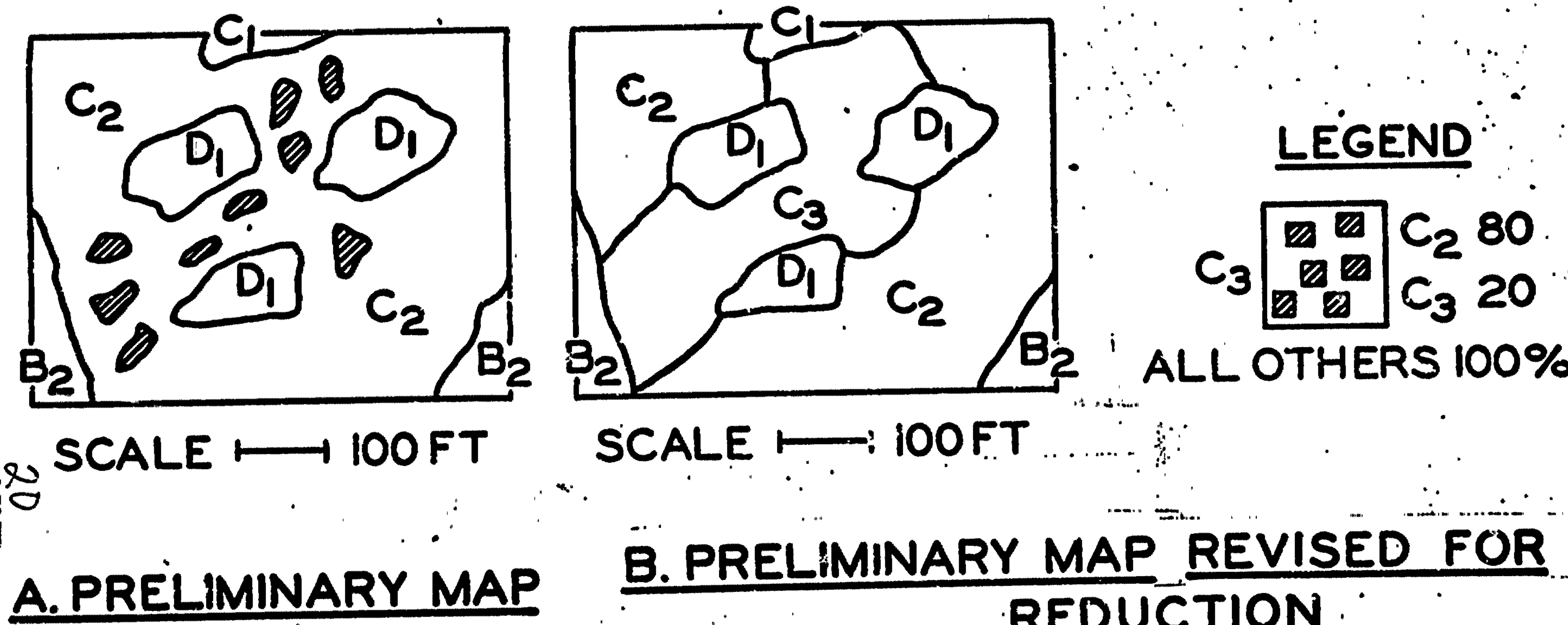
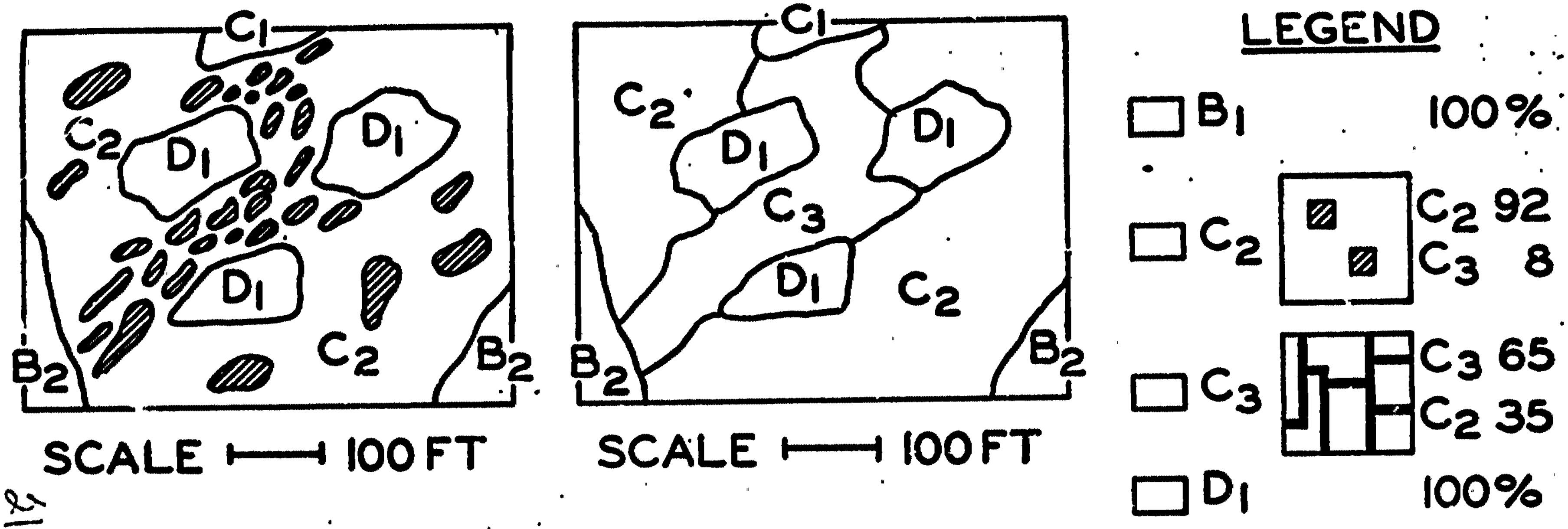


FIG. 4. REVISION FOR REDUCTION, THE CASE WHERE TYPE C_3 OCCURS AS AGGREGATIONS WITHIN TYPE C_2



A. PRELIMINARY MAP

B. PRELIMINARY MAP REVISED FOR REDUCTION

FIG. 5. REVISION FOR REDUCTION, THE CASE WHERE TYPE C_3 HAS OCCUPANCE GREATER THAN DOES C_2

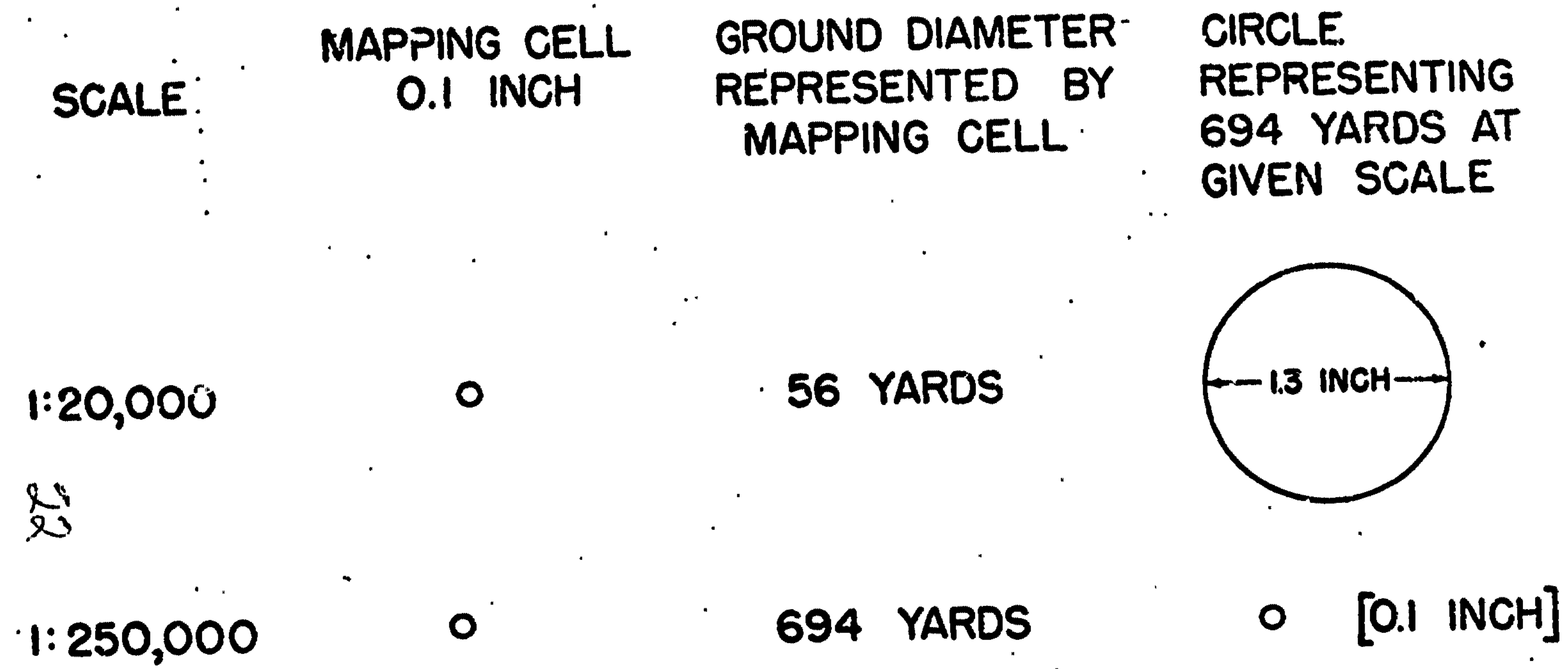


FIGURE 6. RELATIONSHIP OF MAP SCALE AND MAPPING CELL

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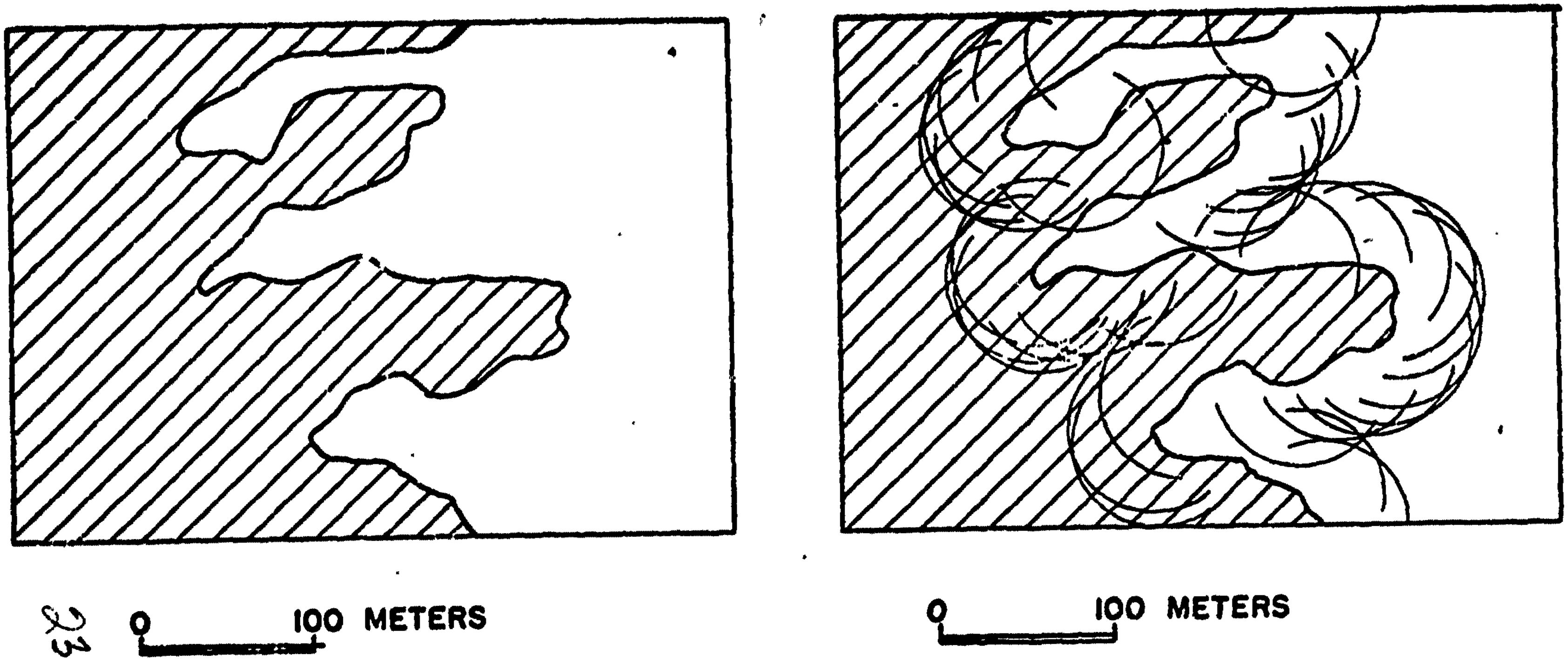
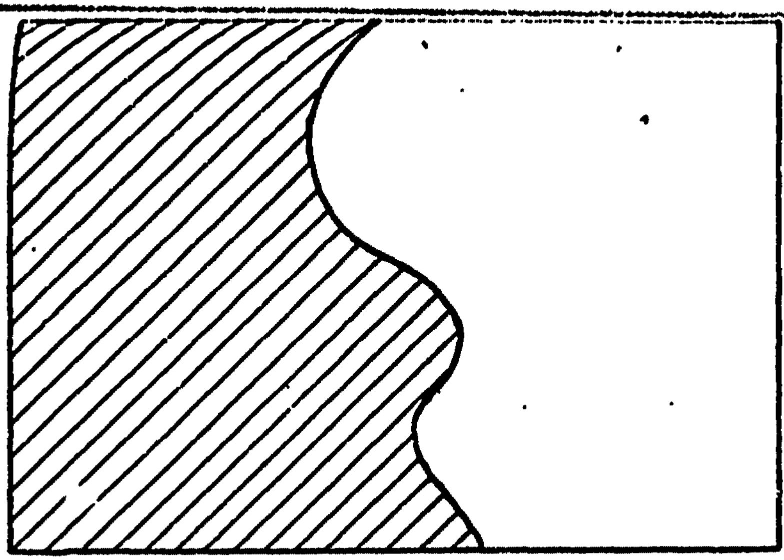


SYMBOL	DEFINITION	RELIABILITY
(blank box)	PRAIRIE	100
(hatched box)	FOREST	100

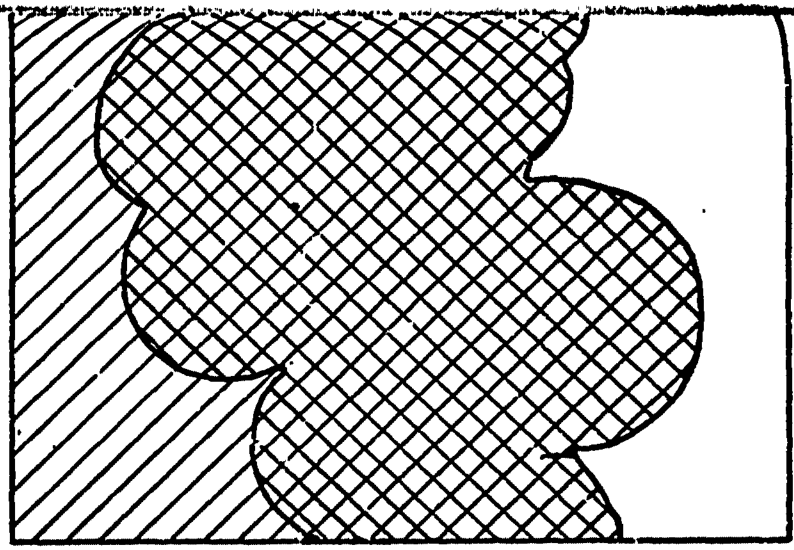
SYMBOL	DEFINITION	RELIABILITY
(blank box)	PRAIRIE	—
(hatched box)	FOREST	—

FIGURES 7A, 7B. BOUNDARY GENERALIZATION BY APPLICATION OF THE MAPPING CELL



0 100 METERS

SYMBOL	DEFINITION	RELIABILITY
	PRAIRIE	85
	FOREST	88



0 100 METERS

SYMBOL	DEFINITION	RELIABILITY
	PRAIRIE	100
	FOREST	100
	PRAIRIE/FOREST	37/63

FIGURES 7C, 7D. BOUNDARY GENERALIZATION BY APPLICATION OF THE MAPPING CELL

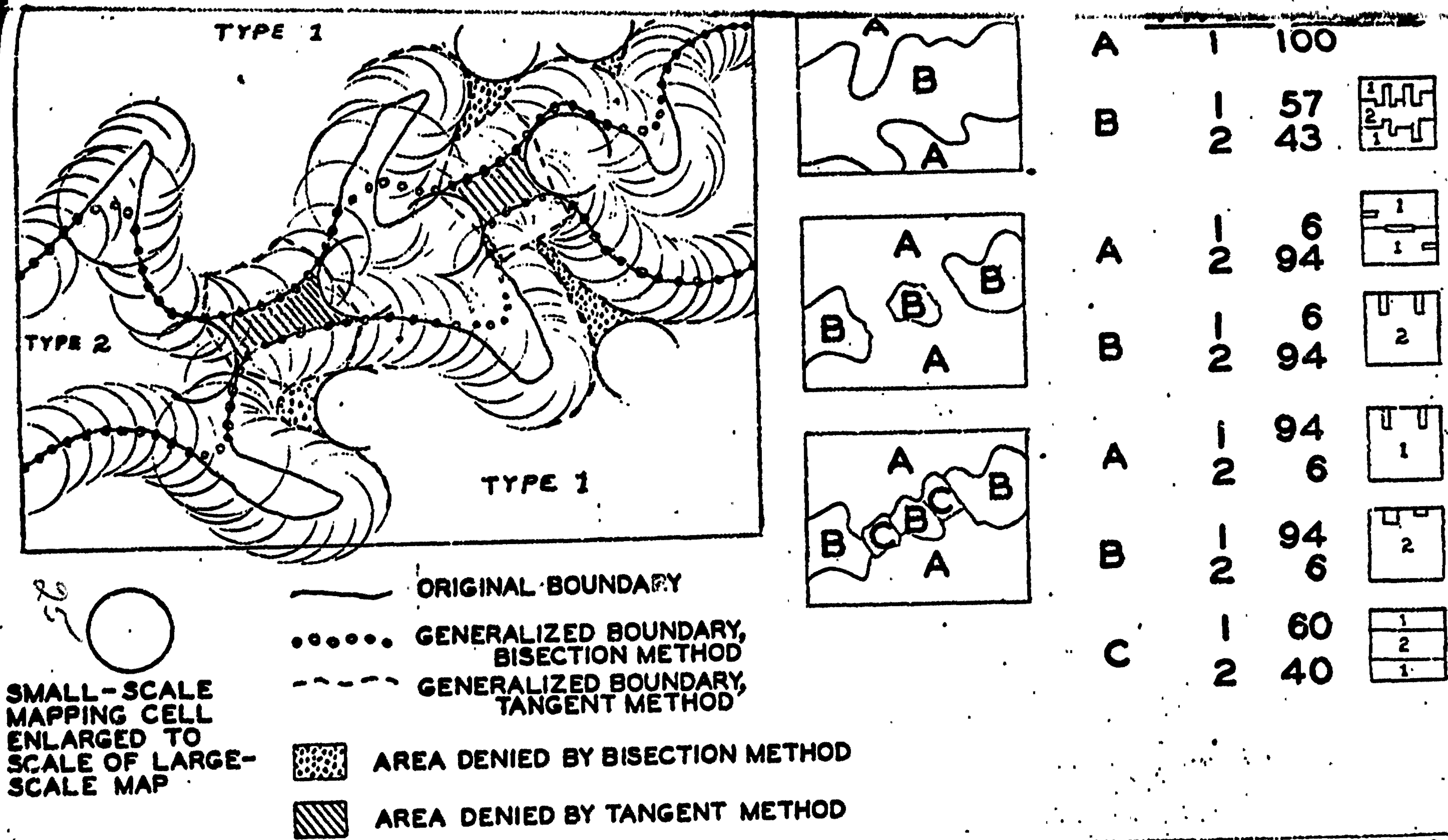
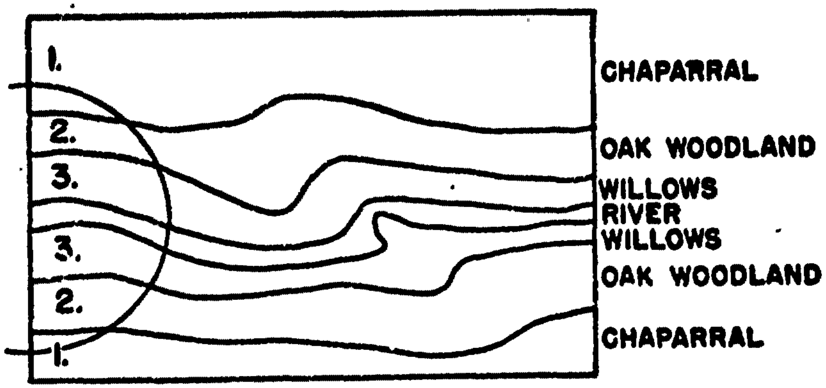


FIG. 8. OCCURRENCE OF UNMAPPABLE AREAS RESULTING FROM GENERALIZATION BY MAPPING CELL TECHNIQUE, AND ALTERNATIVE REDUCED MAPS



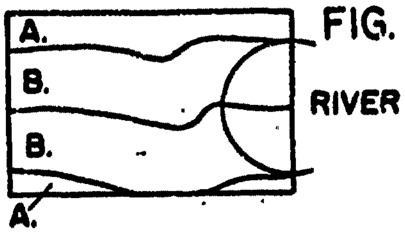
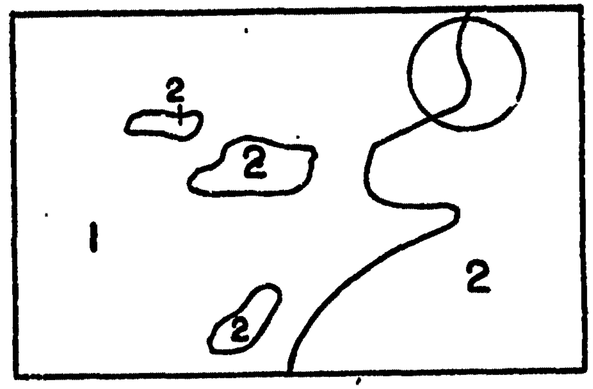


FIG. 9A. NARROW BANDS OR STRIPS

RIVER IS GENERALIZD BY BISECTION; THIS CONTROLS STRIP BOUNDARIES.



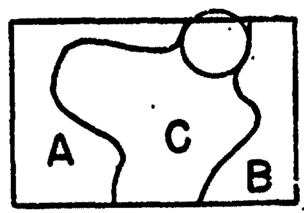
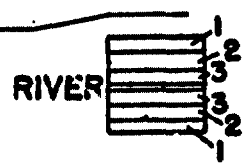


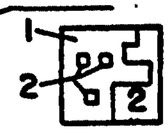
FIG. 9B. TONGUES AND ENCLAVES

(TANGENT METHOD)

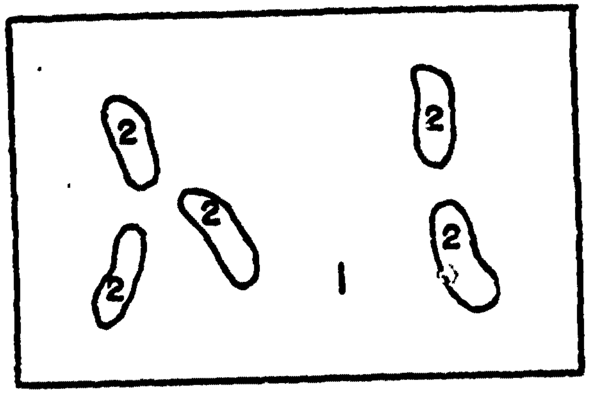
LEGEND FOR SMALL-SCALE MAP

UNIT	COMPONENT TYPES	RELIABILITY	DESCRIPTION
A	1	100	
B	1 2 3 RIVER	30 35 25 10	

LEGEND FOR SMALL-SCALE MAP

UNIT	COMPONENT TYPES	RELIABILITY	DESCRIPTION
A	1	100	
B	2	100	
C	1 2	60 40	

FIGURES 9A, 9B. EXAMPLES OF VARIOUS ARRANGEMENTS OF LARGE-SCALE MAPPING UNITS, WITH POSSIBLE SMALL-SCALE EQUIVALENTS



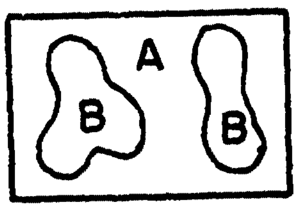


FIG. 9C. ENCLAVES (TANGENT METHOD)

LEGEND FOR SMALL-SCALE MAP

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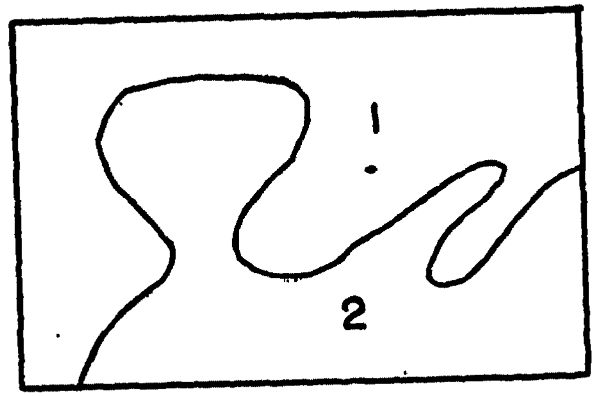
UNIT	COMPONENTS	RELIABILITY	DESCRIPTION
A	1	100	
B	1 2	79 21	



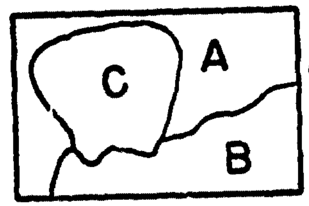
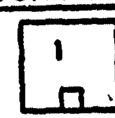
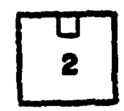
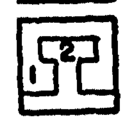


FIG. 9D. LOOPS

(A/B BOUNDARY BY BISECTION METHOD; A/C & C/B BOUNDARIES BY TANGENT METHOD)

LEGEND FOR SMALL-SCALE MAP

UNIT	COMPONENTS	RELIABILITY	DESCRIPTION
A	1 2	95 5	
B	1 2	5 95	
C	1 2	60 40	

FIGURES 9C, 9D. EXAMPLES OF VARIOUS ARRANGEMENTS OF LARGE-SCALE MAPPING UNITS, WITH POSSIBLE SMALL-SCALE EQUIVALENTS

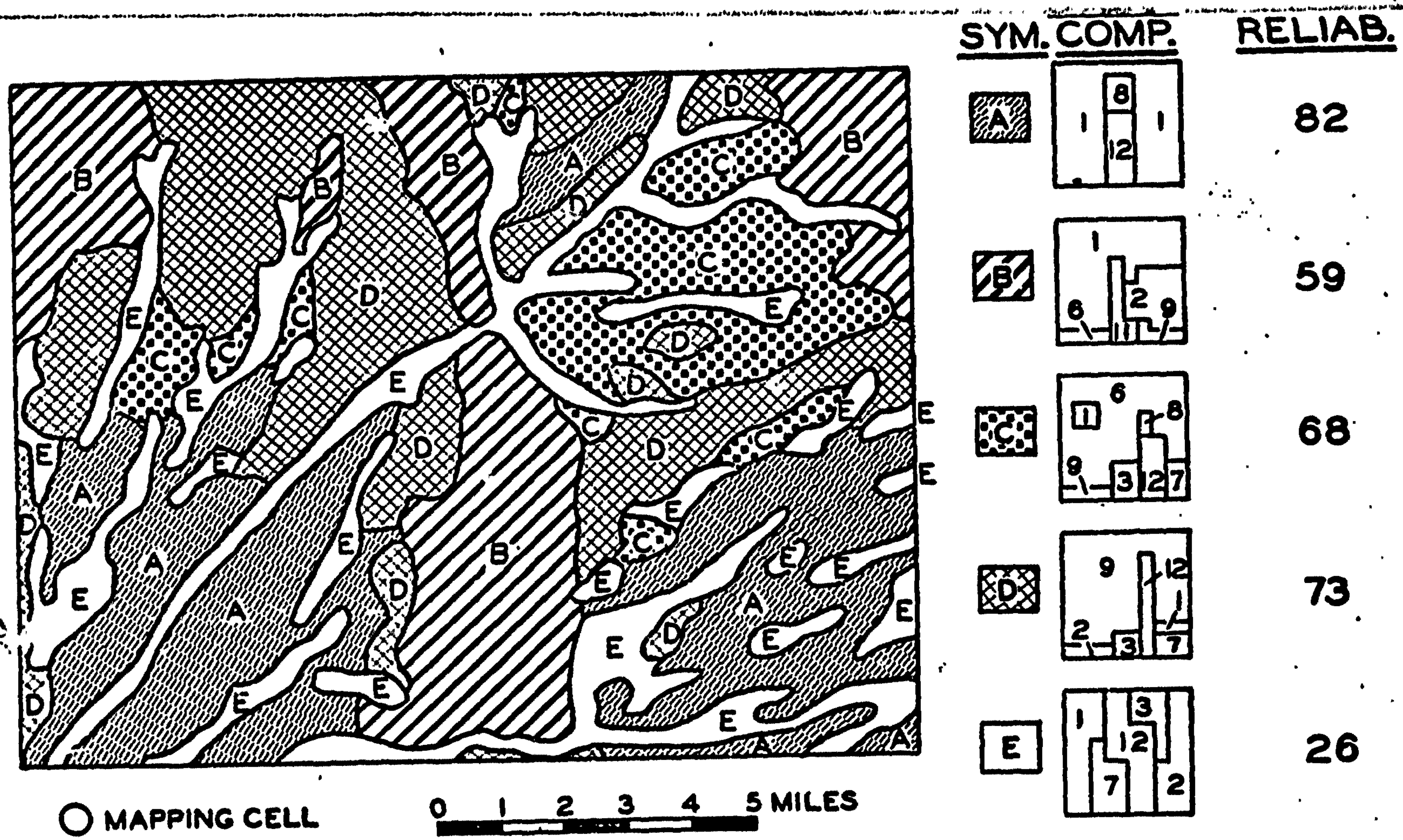


FIG. 10. VEGETATION MAP, PART OF YUMA TEST STATION